OVERVIEW OF FEASIBILITY STUDY ON CONDUCTING OVERFLIGHT MEASUREMENTS OF SHAPED SONIC BOOM SIGNATURES USING RPV'S

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OUTLINE OF PRESENTATION

Before beginning this presentation, it is appropriate to acknowledge the sincere interest and financial support provided by the NASA Langley Research Center under contract NAS9-17900.

An outline of the material to be used in the present paper is given in figure 1. It begins with a indication of the origin and objectives of the feasibility study. This is followed by a discussion of various simulation methods of establishing the persistence of shaped sonic boom signatures to large distances including the use of recoverable RPV/drones. The desirable features to be sought after in an RPV along with a rationale for the selection of a "shaped" sonic boom signature will be addressed. Three candidate vehicles are examined as to their suitability with respect to a number of factors, in particular, modifiability. Area distributions and associated sonic boom signatures of the basic and modified Firebee vehicle will also be shown.

An indication of the scope of the proposed wind tunnel and flight test programs will be presented including measurement technologies and predicted waveforms.

Finally, some remarks will be made summarizing the study and highlighting the key findings. Finally, some remarks will be made summarizing the study and highlighting the key findings.

- Origin / objectives of feasibility study
- Simulation methods
- Desirable features for RPV
- Selection of shaped sonic boom signature
- Candidate vehicles
- Basic / modified Firebee characteristics
- Wind-tunnel and flight programs
- Summary remarks

Figure 1

MAJOR THRUSTS IN SOLUTION TO HSCT OVERLAND SONIC BOOM

The future success of commercial high-speed overland flight will depend, in large part, on providing a solution to the sonic boom problem. Without some unforeseen technological breakthroughs that may eliminate the sonic boom, current efforts are aimed at modifying the boom signature in order to make it more acceptable. The term "more acceptable" infers modifications to the signature that includes not only reducing the peak overpressure (or intensity of the boom), but shaping the signature to look something other than the typical N-wave. Variations include so-called "flat-top" waveforms, "ramp-type," and variations of each (that increase shock rise times and change frequency spectra) have all been shown to reduce loudness and noisiness[1] at least to observers out-of-doors. Sonic boom waveform (signature) modifications must also benefit "indoor" listeners and also reduce structural response.

Three major thrusts are required in the solution of the sonic boom problem associated with overland flights of a High-Speed Civil Transport (HSCT), as indicated by the three outer circles shown in figure 2. These three major thrusts include the establishment of criteria for an acceptable waveform, being able to design a viable aircraft to an existing shaped (or acceptable) waveform, and quantifying the effects of the atmosphere through which this shaped waveform will propagate. These three major thrusts are, in fact, the three major research priorities that were recognized by a panel of experts from industry, government, and universities as the key areas to be addressed.[2] A reasonable data base from small model wind tunnel tests[3,4] and theory[5,6] exists indicating that vehicles can be designed to produce modified sonic boom signatures (non N-wave types) of the type that may be more acceptable from a people and structural response aspect.

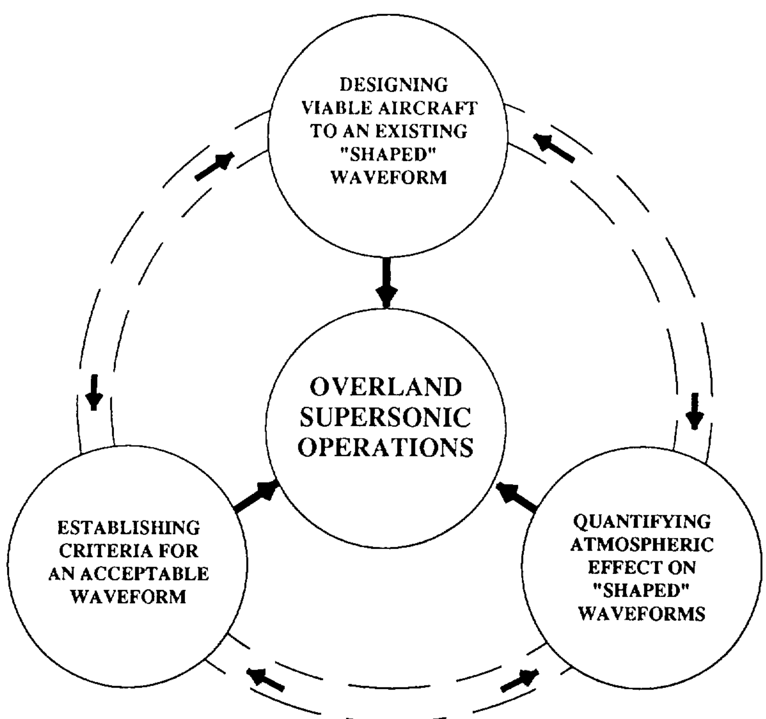

Figure 2

MEASURED SONIC BOOM SIGNATURES OF A BASIC AND MODIFIED MODEL IN THE WIND TUNNEL

An indication of the status of sonic boom signature modifications as established by wind tunnel model tests and theory is given in figure 3. Measured sonic boom signatures are shown for various distances from the models for two vehicle configurations, one designated a basic body which is to produce an N-wave signature in the far field, and the other designated a modified body which is to produce a flat-top signature in the far field.

Signature measurements at 2.5, 5, and 10 body lengths (h/l) from the model illustrate the development of the waveforms for the two models. Note that the basic configuration signature sketches to the left side of figure 3, which is to result in an N-wave on the far field, still retains the multiple saw-tooth shock characteristic out to 10 body lengths. However, the signatures on the right side of the figure relating to the model designed to produce a flat-top signature in the far field show flat-top waveforms at all three measurement positions. In this case, tunnel test section length and model size constraints limit the furthest measurement to 10 body lengths from the model.

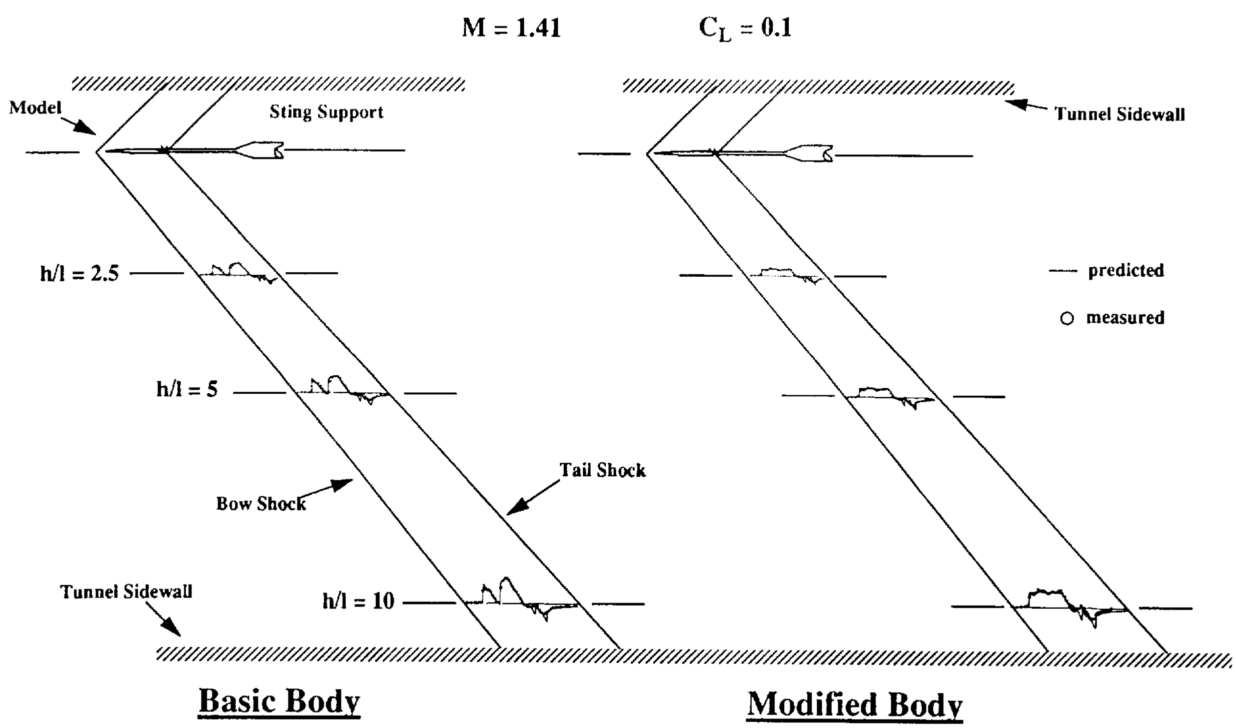

Figure 3

SCHEMATICS OF SONIC BOOM SIGNATURE DEVELOPMENT

Wind tunnel model near-field signatures of the type shown in figure 3 are then inserted into the sonic boom prediction program and propagated to distances/body lengths equivalent to full-scale aircraft flying at cruise altitudes (h/l ~ 300) and the resulting sonic boom signatures are established as illustrated by the shock-field signature schematics given in figure 4. Although the original intent of figure 4 was to highlight the so-called low-boom high-drag paradox,[2] the figure is used herein to illustrate the rapid coalescence of the near- and mid-shock field of the basic saw-tooth signature into an N-wave at the ground. The modified flat-top signature appears to propagate as a flat-top waveform from near- and mid-field to the far-field at ground level. Experimental verification of the coalescence of the basic saw-tooth signature into an N-wave, as predicted by theory and wind tunnel model tests, has been established from in-flight measurements in the near- and far-field and at a ground level for large aircraft flying at high altitudes.[7,8,9,10] A corresponding full-scale/large-scale experimental verification for configurations designed to produce "shaped" (non N-wave signatures) waveforms has not yet been demonstrated. In fact, of the more than 13,000 sonic boom signatures that have been measured to date involving some 18 different size, shape, and weight aircraft and even space vehicles operating at a range of Mach numbers to 23 and heights to 250,000 feet, all have had typical saw-tooth/N-wave shapes. Thus there is the need for experimentally establishing whether a "shaped" waveform, shown to be "do-able" on wind tunnel models out to about 10 body lengths, will persist out to representative full-scale flight conditions of about 200 to 300 body lengths.

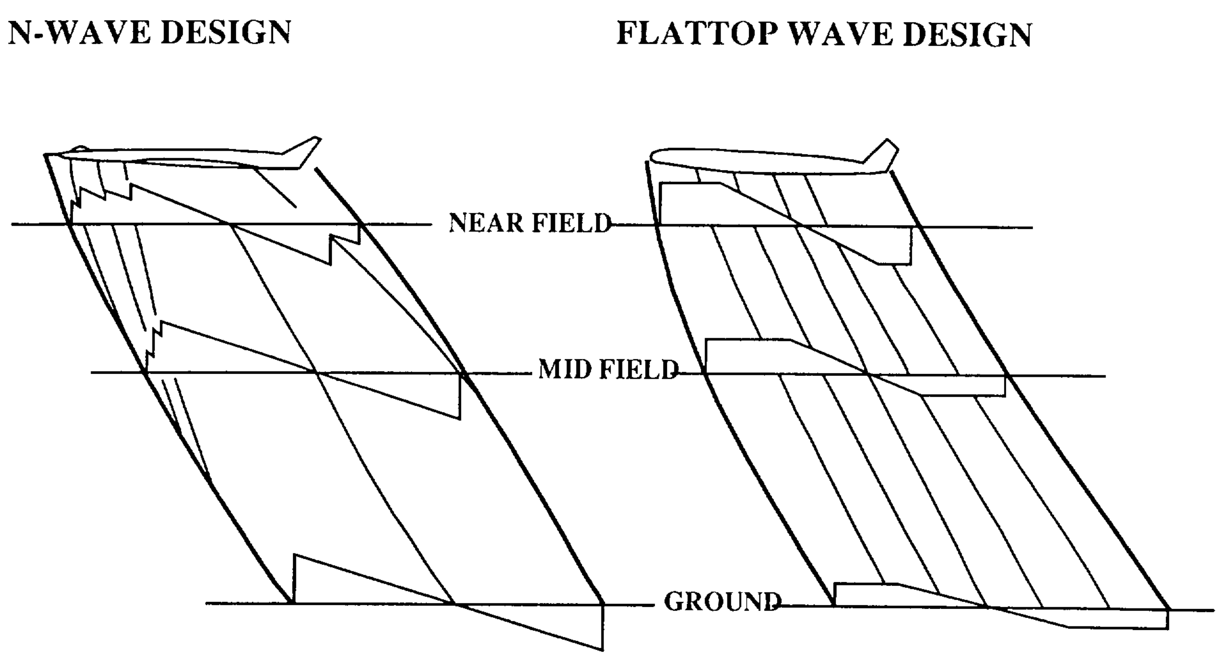

Figure 4

OBJECTIVES OF FEASIBILITY STUDY

As indicated in figure 5, there are two objectives to be addressed in the present study. The primary objective is to assess the feasibility of utilizing relatively large remotely piloted vehicles (RPV's) or drones to experimentally establish the persistence of "shaped" sonic boom signatures out to representative cruise flight distances (200 to 300 body lengths) in a real atmosphere. A secondary objective would be to provide an early indication of the influence of the atmosphere on "shaped" waveforms as they propagate from the vehicle to the ground. This would be especially informative since the present data base on atmospheric influences on sonic boom signatures is based entirely on saw-tooth/N-wave type sonic boom shapes.

① Experimentally establishing whether a "shaped" waveform, shown to be "do-able" on wind-tunnel models out to about 10 body lengths, will persist out to representative flight conditions of about 200-300 body lengths.

② Obtain early indication of influence of atmosphere on "shaped" waveform.

Figure 5

METHODS OF ESTABLISHING PERSISTENCE OF MODIFIED SONIC BOOM SIGNATURES

In addition to the preferred use of recoverable RPV targets/drones to accomplish the objectives of this feasibility study that is, in fact, the primary thrust of the current study, six other approaches to establishing the persistence of modified sonic boom signatures were identified and are listed in figure 6. An examination was made of the pros and cons of each technique. The six techniques consist of the use of very large supersonic wind tunnels and very small models, the use of large ballistic range firing equivalent bodies of revolution, the use of a whirling-arm technique and complete vehicle geometries (winged bodies) in a large anechoic wind tunnel or enclosure, the use of a full-scale rocket sled track, the adapting of a model shape nose probe attached to a current supersonic aircraft and, finally, the use of lower cost nonrecoverable RPV targets/missiles.

Study findings regarding these alternate approaches to experimentally establishing the persistence of shaped sonic boom signatures to very large distances were, for the most part, not suitable. Only two of the six techniques addressed are considered promising. The following remarks highlight the study findings regarding the six alternate schemes. The use of nonrecoverable vehicles and missiles were deemed inappropriate since the required sonic boom shape modifications would have a significant influence on the basic flight characteristics and stability and control. Costs are also a significant factor since each flight would require a vehicle and its associated geometric modifications. Very large wind tunnels, supersonic sled tracks, and aircraft nose probes are also considered not applicable; large wind tunnels because they are nonexistent, sled tracks because of the presence of the ground surface, and nose probes because of the overwhelming influence of the airplane shock flow field. The ballistic range and whirling-arm techniques are, however, considered applicable, especially the former.[11] Each of these latter two simulation techniques may be used to generate a substantial data base on sonic boom signatures relative to vehicle geometries and atmospheric influences; the ballistics range using equivalent bodies of revolution and the whirling-arm technique using complete airplane geometries (winged vehicles).

- Large supersonic tunnels / small models / uniform “atmosphere”
- Ballistics range / bodies of revolution / variable “atmosphere”
- Whirling arm / winged model / anechoic tunnel / variable “atmosphere”
- Supersonic rocket sled track
- Nose probe on supersonic aircraft
- Lower cost non-recoverable RPV vehicles / missiles
- ✓ Controllable / recoverable RPV targets / drones

Figure 6

COMPARISON OF REAL AND SCALED SIMULATION

A fundamental question that needs to be addressed regarding the present feasibility study is whether or not the proposed scheme to utilize relatively large RPV's will more firmly establish the credibility of "modified" waveforms. Some of the concerns being expressed can be illustrated with the use of figure 7. Shown in the figure are two schematics of the shock-signature patterns representing the full-scale real airplane case of a 200-foot long vehicle flying supersonically at 60,000-feet altitude (300 body lengths) as shown on the left side of the figure, and the situation for a 30-foot RPV flying supersonically at about 9,000-feet altitude (also 300 body lengths) shown on the right side of the figure. Although the requirement to simulate the 300 body length equivalency is duplicated for both full-scale and RPV cases, the consistency of the atmosphere in terms of the influence of atmospheric pressure, temperature, sound speed, density, oxygen-nitrogen, and relative humidity at the vehicle altitudes is not duplicated. In addition, the so-called "scaled height" as it relates to signature freezing" must be addressed. The questions, therefore, are twofold: first, do atmospheric parameters play a significant role in the persistence of "modified" signatures; second, is "scale height" required to establish "frozen" modified signatures? Discussions relative to these two issues suggest that confirmation of the persistence of "modified" sonic boom signatures will be established based upon the simulation of equivalent body lengths, especially since atmospheric density is increasing with decreasing altitude.

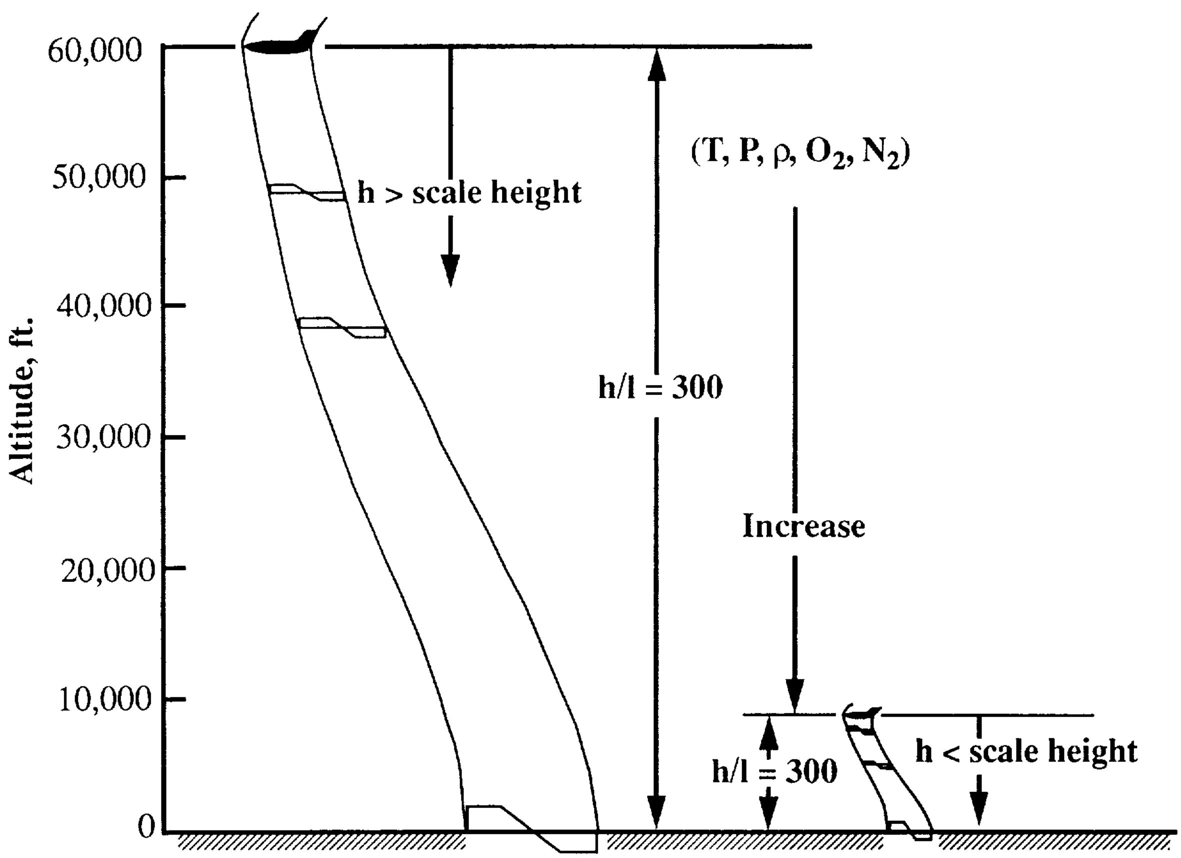

Figure 7

DESIRABLE RPV FEATURES

In selecting a recoverable RPV, a number of requirements were addressed along with such factors as availability, suitability, costs, and operational/launch capability. Seven features were identified as being desirable, if not required, in the RPV selection and these are listed in figure 8. The vehicle should be relatively large (20 to 30 feet in length), capable of Mach 1.2 to 2.5 ranges at altitudes of about 5,000 to 10,000 feet, be controllable, able to hold steady-level Mach altitude for about 5 miles, be ground launched, recoverable, and modifiable.

Vehicle length is critical in establishing its operating altitude as established by the 200 to 300 body length simulation. Since the secondary objective of this effort is to acquire an early look at the effects of atmospheric turbulence in the first 1,000 to 3,000 feet or so of the Earth's boundary layer, vehicle flight altitudes greater than 3,000 are desirable. Thus, a minimum vehicle length of about 13 feet is established. Sonic boom minimization studies have focussed on the Mach range 2.0 to 3.0 but have also been conducted at Mach numbers as low as 1.5.[12] The minimization concept and signature persistence should be demonstrable at even lower Mach numbers. The only real concern is that the vehicle be able to operate a speed sufficiently greater than the cutoff Mach number (Mach number below which boom will not reach the ground). For altitudes from 5,000 to 10,000 feet, the highest cut-off Mach number is the order of 1.1 or less.[13] Thus, flights at Mach 1.2 and greater are appropriate.

Since the vehicle is to be modified in the sense of changing its equivalent area distribution, it is preferred to make the area additions to the nonlifting portions of the vehicle which will, hopefully, have little effect on the basic vehicle loads and stability and control. The drag of the modified vehicle will differ from the basic configuration.

Finally, a ground-launched recoverable vehicle will not only be very cost effective, it will eliminate a number of activities that could complicate the program and degrade the safety aspect of the flight operations.

- Relatively large size (20 - 30 ft.)
- M = 1.2 - 2.5 at 5,000 - 10,000 ft.
- Controllable flight
- Hold steady-level Mach-altitude for 5 miles
- Ground-launched
- Recoverable
- Modifiable

Figure 8

SIGNIFICANT FEATURES OF MODIFIED SONIC BOOM SIGNATURE

In order to establish the persistence of modified sonic boom signatures to long distances, a number of concerns must be addressed relative to the signature characteristics and these are indicated in figure 9. First of all, the shape of the signature is of paramount importance. That is to say that the overpressure level of the "shaped" signature is of secondary importance in the sense that "modified" or "shaped" RPV/drone may have Δp's larger than the "basic" unmodified vehicle. Also, the "shaped" signature need not have similar bow and tail shocks. It is known from laboratory subjective response studies that any modifications to sonic boom signatures should be equally applied to both bow and tail shocks; that is, if a flat-top signature is developed, it should be symmetrical in regards to bow and tail shocks. Waveform symmetry places a significant constraint on vehicle modifications. On the other hand, designing a vehicle to produce a nonsymmetrical "modified" waveform is more easily acquired. Finally, the "modified" signature must be distinguishable from an N-wave as measured at ground level (200 to 300 body lengths).

- Shape of signature is of paramount importance
- Δp level of "shaped" signature is of secondary importance
- "Shaped" signature not required to be symmetrical
- "Shaped" signature must be distinguishable from an N-wave

Figure 9

RELATIONSHIP OF SIGNATURE SHAPES TO VEHICLE AREA DEVELOPMENT

In order to design a vehicle to have a "modified" or "shaped" sonic boom waveform, it must combine its equivalent area due to both volume and lift to produce a reasonably smooth total area development along its longitudinal axis similar to the ones shown in the lower portion of figure 10.[2] Note that very little change in area development is required to the vehicle in order to produce either a flat-top waveform, shown to the left of the figure, or a ramp-type waveform shown to the right of the figure. However, each of these equivalent area distributions are considerably altered from that associated with a basic/standard vehicle design that produces an N-waveform (as illustrated in the upper center portion of the figure). Since the required modifications to any RPV/drone must be made in terms of "adding to" rather than "taking away" area, the subject test vehicle will most likely require a nose extension along with area additions mid-ship on the vehicle.

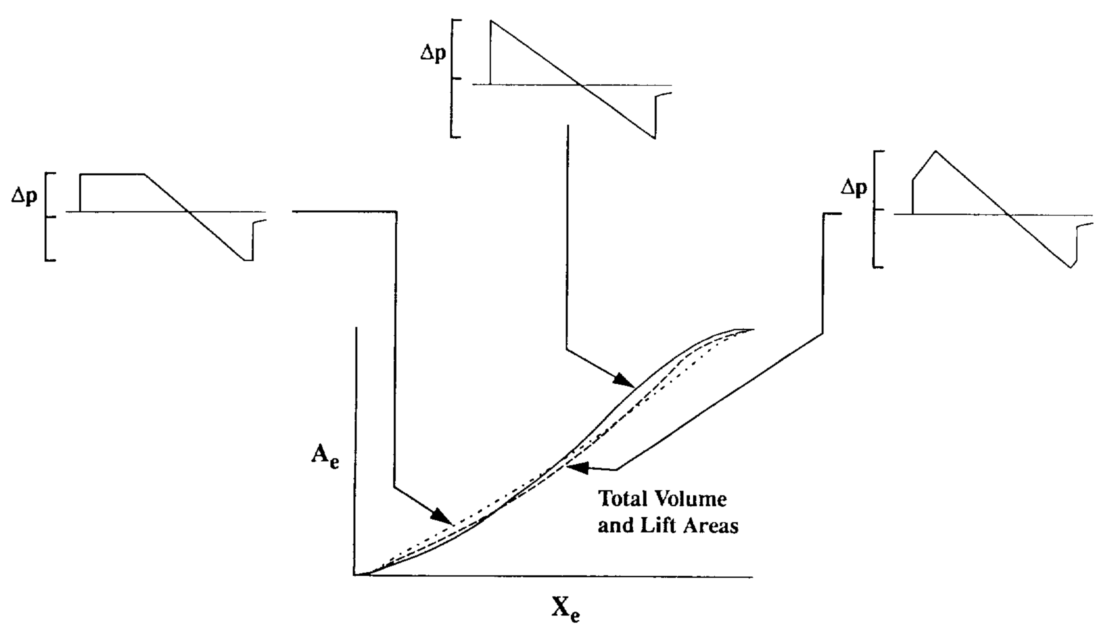

Figure 10

SPECTRAL CHARACTERISTICS OF BASIC AND MODIFIED SIGNATURES

Since the present study is aimed at developing "modified" signatures of the flat-top and ramp-type waveforms that are nonsymmetrical, that is, changing the positive portion of the signature but not the negative phase, it is of importance to examine the signature spectra of each of these types of waveforms as compared to the basic symmetrical N-wave to see if any significant changes are evident. A comparison of the spectra for an N-wave, a flat-top positive phase waveform, and a ramp-type positive phase waveform is given in figure 11. Little if any difference is noted to exist between the three waveform spectra. This suggests that from the standpoint of signature identification due to atmospheric influences, there are no driving reasons to select a ramp-type "modified" signature over one having a flat-top waveform shape. This allows for some latitude in the selection of and modification to a particular RPV/drone configuration.

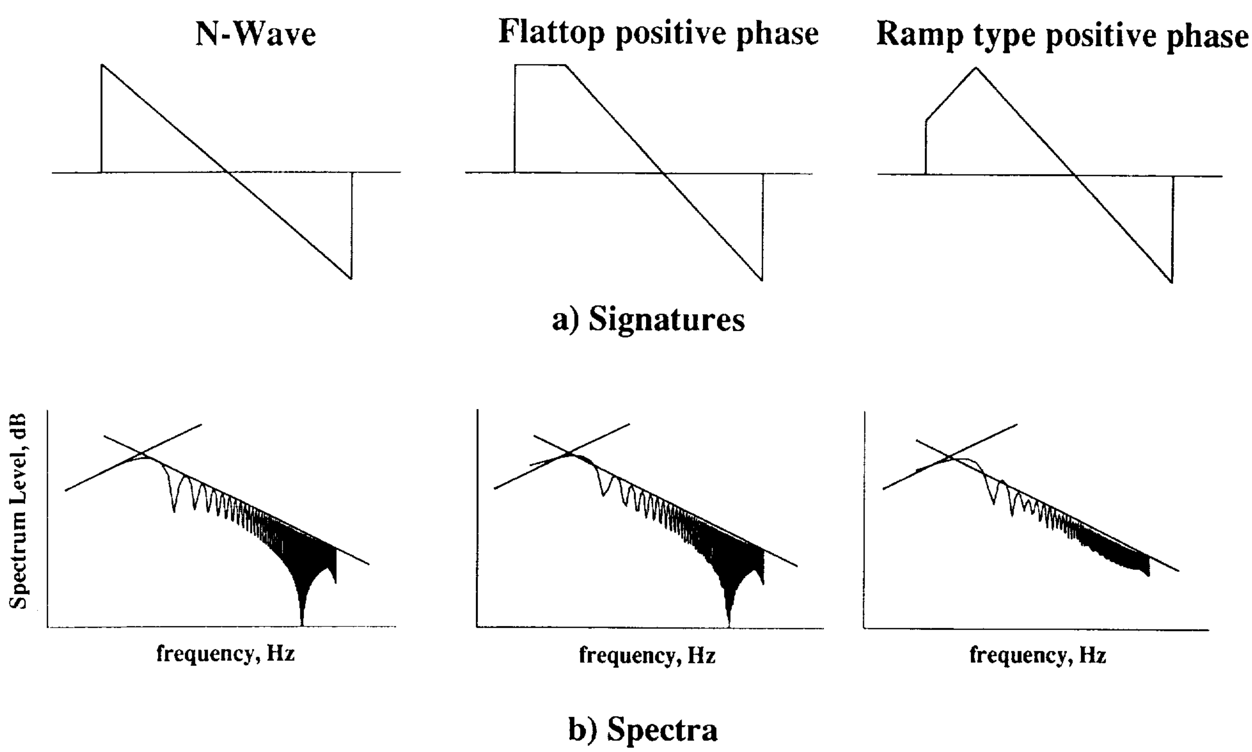

Figure 11

CANDIDATE TEST VEHICLES CONSIDERED IN STUDY

There are three candidates in the class of recoverable vehicles that were considered in this study and these are shown in figure 12. The first of these recoverable vehicles is the Teledyne Ryan Firebee (BQM-34 E) shown in the top portion of the figure. The Firebee is a wing-tailed aircraft type controllable-recoverable supersonic RPV target of about 28 feet in length, weighs about 1,900 pounds, is powered by a J-69 turbojet, and is of 1970 vintage. It can be either air- or ground-launched and has a Mach capability of about 1.3 at about 8,000 feet increasing to Mach 1.5 at 20,000 feet. Only about eight of these vehicles are in existence since they have been phased out of operation by the Navy and Air Force. Two complete vehicles with spares (except engines) are currently retained by NASA Langley Research Center. These vehicles were routinely launched at Pt. Mugu, Puerto Rico, and Tyndall and have experienced reuse rates of about 10 sorties. Currently, the vehicle is being phased out of DoD operations.

A QF-4 drone aircraft was the second recoverable vehicle to be considered in this study and is shown in the center portion of figure 12. The QF-4 is a drone version of the F-4 fighter and is about 58 feet in length, has an average weight of about 45,000 pounds, is powered by two J-79 turbojet engines, and is of 1960 vintage. As a drone, it is remotely operated as a normal aircraft in terms of performing takeoff-climbouts and landings and supersonic flights. It has a Mach capability of about 1.3 to 1.4 at about 18,000 feet. It is understood that the QF-4 drones will probably be in use at Pt. Mugu for the next decade or so.

The third recoverable vehicle considered is the Martin Marietta SLAT shown in the lower portion of the figure. It is a finned-missile type controllable-recoverable supersonic RPV target of about 18 feet in length, weighs about 2,500 pounds, is powered by an airbreathing ramjet and is of 1990 vintage. It is airlaunched and has a Mach capability of 2.5 at 8,000 feet. The "SLAT" is still in the development stage and is being launch-tested at Pt. Mugu.

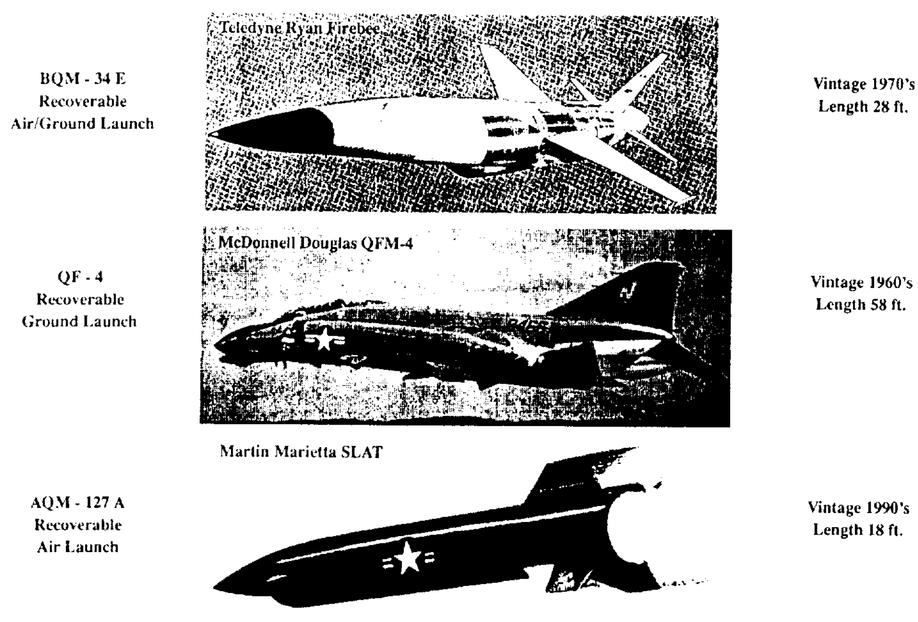

Figure 12

AREA DISTRIBUTIONS AND SONIC BOOM SIGNATURES OF CANDIDATE VEHICLES

The most significant feature in the selection of an appropriate test vehicle, regardless of cost and availability, is the "modifiability" of the vehicle. The area developments of the Firebee, QF-4, and SLAT are given in figure 13 along with the associated sonic boom signature that would be observed at the 300 body length and corresponding Mach-altitude combinations. Note that all three signatures are of the "saw-tooth" character and are rapidly approaching an N-wave shape. In addition, the equivalent area distributions for the "airplane type" Firebee BQM-34 E and the QF-4 drone airplane are similar since they are both winged-tailed configurations and, thus, more gradual in their area buildup than for the finned-missile SLAT which displayed a very rapid area buildup from the nose to a flatter more constant area development along the mid-aft constant diameter portion of this vehicle. Thus, in order to generate a "shaped" signature (flat or ramp type) out of any of the three vehicles, extensions to the forward portion of the vehicles will be required in order to generate the typical area buildups indicated previously on figure 10. Extension of the nose section of the SLAT to provide for the required more gradual area buildup to produce a ramp or flat-top sonic boom waveform could seriously alter the existing matched nose-inlet design of the basic SLAT vehicle. Area must also be added to the mid-aft sections in order to maintain a smoothly increasing area development.

Both the Firebee RPV and the QF-4 drone have equivalent area developments that are more amenable to modification in terms of providing for a ramp or flat top type sonic boom signature. Because the Firebee RPV has a higher fineness ratio than the QF-4, it also has a more gradual equivalent area development as noted in figure 13. Extension of the nose section on the smaller, more slender, Firebee would appear to present less of a problem than to do the same procedure on the full-scale QF-4 drone airplane. In addition, the two inlets on each side of the QF-4 could present more difficulties than the single "belly" type inlet on the Firebee in terms of uniformity of flow and boundary layer buildup. Finally, the necessary area additions required on the mid-sections of each vehicle suggest that the Firebee would be least difficult to alter.

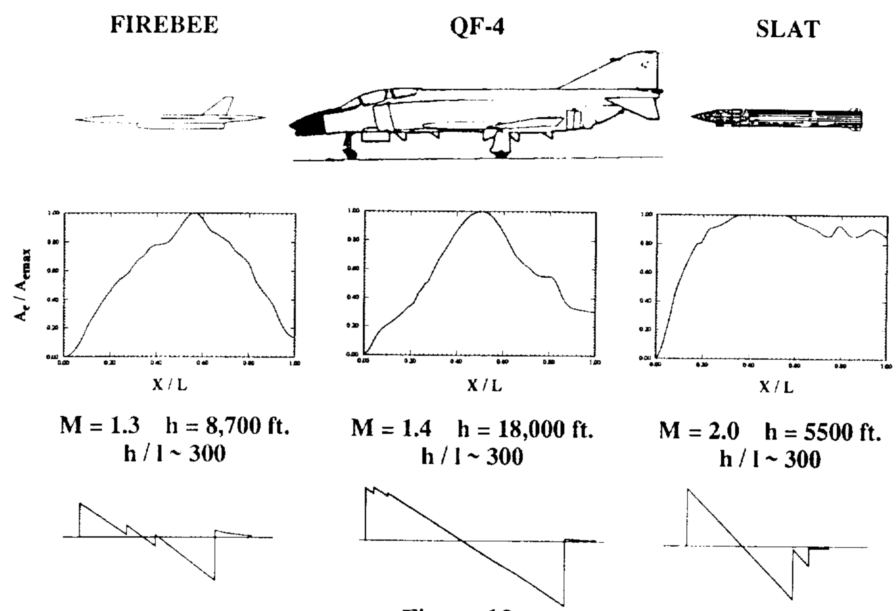

Figure 13

AREA DISTRIBUTIONS AND SIGNATURE CHARACTERISTICS OF FIREBEE CONFIGURATIONS

Selection of the 28-foot long Firebee vehicle as a primary candidate sets the flight altitude-Mach combination of 8,700 feet (300 body lengths) and 1.3, respectively. At these given Mach-altitude conditions, calculations were made of the equivalent area distributions for the basic vehicle and the equivalent area developments required to produce a boom signature having a flat top positive phase and one having a ramp-positive phase signature at ground level. These results are presented in figure 14. At the top of the figure are schematic illustrations of the profile view of the basic Firebee and profiles of the two altered vehicles that are designed to give a flat-top and ramp-type signature. Note that the nose and midsection portions (beneath the inlet) of the latter two vehicles required modification in the form of a nose extension and added area to the midsection. The basic (unmodified) vehicle area distribution shown on the left part of the figure has been carried over to the other two area plots as dashed lines in order to give a visual feel for where area (or volume) had to be added in order to end up with the area developments that produce the flat-top and ramp-type positive phase of the boom signature.

On examining the two modified signatures in terms of their "distinguishability" from the basic Firebee signature (almost an N-wave) it would appear that the flat top positive phase waveform would be preferred over that of the ramp type since the later appears not too far from becoming an N-wave. In either case, it would be highly desirable to have a flat-top waveform with as long a "flat" duration as possible or a ramp-type with a "large" ramp (i.e., very little initial vertical bow-shock rise) as possible. Increasing the boom signature emphasis of the flat top and ramp characteristics required, primarily, greater extensions to the vehicle nose than the present 3.0 feet for the two cases shown.

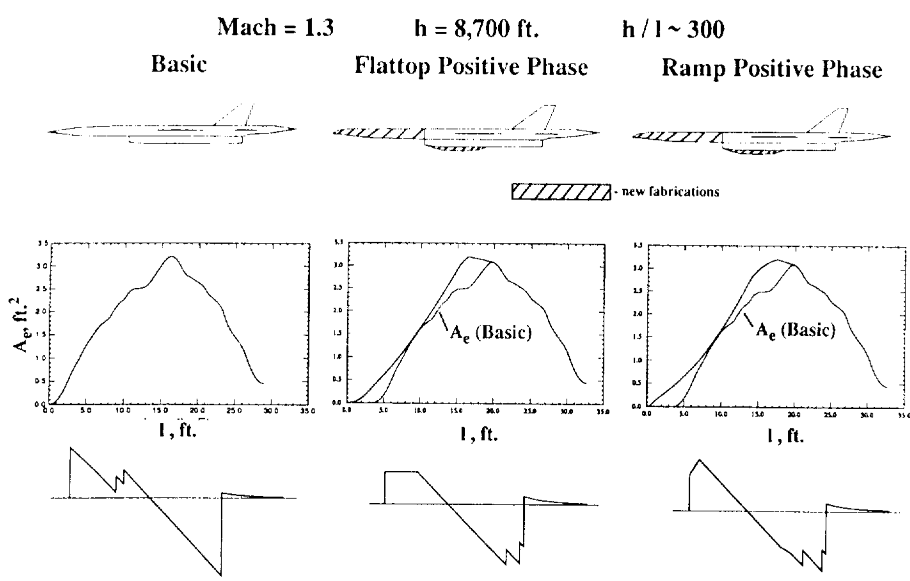

Figure 14

SCOPE OF WIND TUNNEL AND FLIGHT TEST

The scope of the Firebee wind tunnel and flight test program may be illustrated with the aid of figure 15. As indicated by the upper portion of the figure, sonic boom and force models of the basic and modified configurations would be tested at Mach 1.25 and 1.5 in the NASA LaRC 8-foot transonic tunnel (8-ft. TT) and Unitary Plan Wind Tunnel (UPWT), respectively. One model 1-foot length, considered large enough to provide geometric fidelity and also to house a six-component internally mounted strain-gage balance, would suffice for both sonic boom and force tests in each facility and permit boom signature measurements of from 1 to 4 body lengths from the model. A single model with interchangeable nose and belly sections would be utilized for the basic and modified vehicles.

Force tests will establish whether the sonic boom modifications significantly alter the vehicle flight characteristics. Boom tests will provide confirmation of and guidance to the flight test program with respect to the sonic boom signatures expected for the baseline and modified vehicles. Pressure signatures in the near-field from 1 to 4 body lengths would be made for zero-lift and at angles of attack associated with cruise. The flight test program would begin upon completion of the wind tunnel tests. As noted in the lower portion of figure 15, the primary tests, (those required to accomplishing the primary objective) are indicated by the solid lines. A set of desirable tests (designed to accomplish the secondary objective) are indicated by the dashed lines. Note that the primary flight tests (four blocks to the left of the figure) are conducted under minimal atmospheric influences and involve a minimum of two passes each of the baseline and modified vehicles at the design Mach-altitude conditions of 1.3 and 8,500 feet, respectively (300 body lengths), followed by a similar set of runs at Mach 1.5 and 20,000 feet (700 body lengths).

Depending on the Firebee flight recovery success rate, the basic and modified vehicles could be flown at repeat conditions of the Mach-altitude for highly active lower-layer atmospheric conditions (represented by the four boxes to the right of figure 13). Thus, an early indication of the influence of the lower turbulent layers of the atmosphere on modified signatures will be observed.

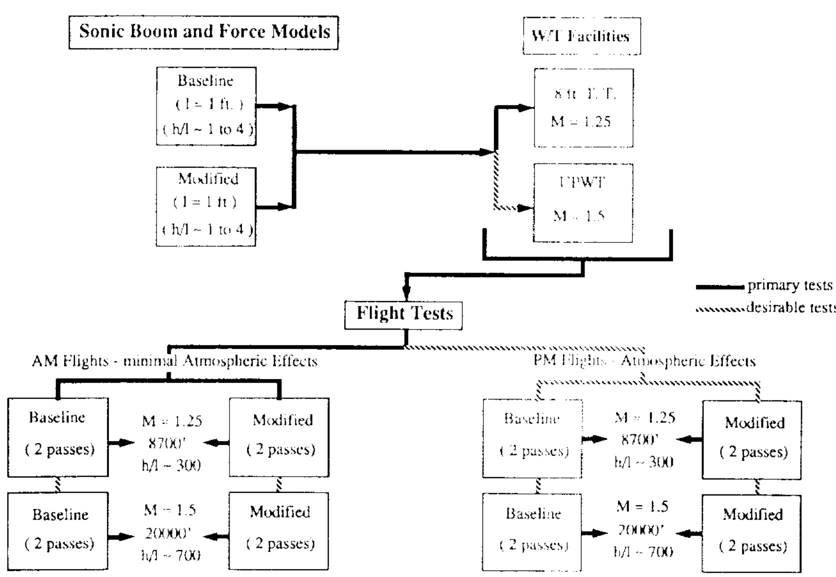

Figure 15

PREDICTED SONIC BOOM SIGNATURES FOR WIND TUNNEL TESTS OF FIREBEE MODELS

The predicted sonic boom signatures for the wind tunnel tests of the one-foot model representing the baseline Firebee configuration and one modified to produce a flat top or ramp positive phase signatures operating at Mach 1.25 in the 8-foot transonic tunnel and at distances of 1, 2, 3, and 4 body lengths (h/l) from the model are illustrated in figure 16. The signatures are drawn approximately to scale in terms of the pressure and time scale in order to provide a better feel for how much change is taking place in the signature characteristics as distance from the model is increased and, also, to provide a view of the difference between the basic and modified signatures. Such comparisons will provide insights into the final selection of a modified waveform relative to the final vehicle design. Note that the signatures are fairly complex in terms of number of shocks and that both the flat top positive phase and the ramp type positive phase signatures persist at all distances from the model.

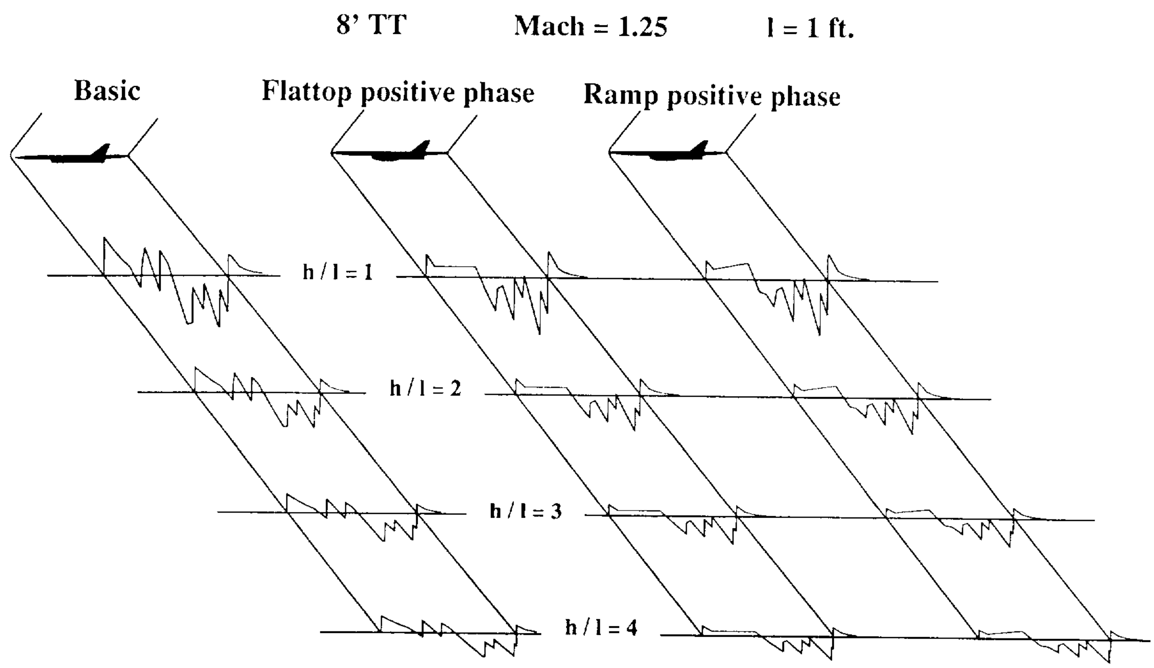

Figure 16

PREDICTED SONIC BOOM SIGNATURES FOR FLIGHTS OF FULL-SCALE FIREBEE VEHICLES

The predicted sonic boom signatures for flights of the full-scale 28-foot Firebee and one modified to produce the flat top or ramp positive phase signatures, operating at Mach 1.25 and at 8,700-feet altitude are shown for distances of 50, 100, 200, and 300 body lengths from the vehicle in figure 17. Once again, as for the wind tunnel case, the signatures are plotted to scale in terms of pressure and time so that a visual display of what would be observed if measurements could be made at each of the distances that the calculated signatures are shown. Note that the basic Firebee (unmodified) signature develops from a fairly complex "sawtooth" waveform in the near-field to a near N-wave at ground level. The two modified signatures retain their pronounced flat top and ramp character out to 100 or so body lengths. As distance increases to 300 body lengths, the ramp type waveform is beginning to steepen into a near N-wave. The flat top waveform, however, is still quite distinguishable.

In addition to the planned sonic boom measurements at ground level (300 body lengths), it also appears feasible to acquire measurements at 100 and 200 body lengths from the vehicle using an airborne measurement planform. Such near-and mid-field signature measurements will greatly enhance the program findings and add significant insight and confidence in sonic boom signature minimization as it relates to vehicle design.

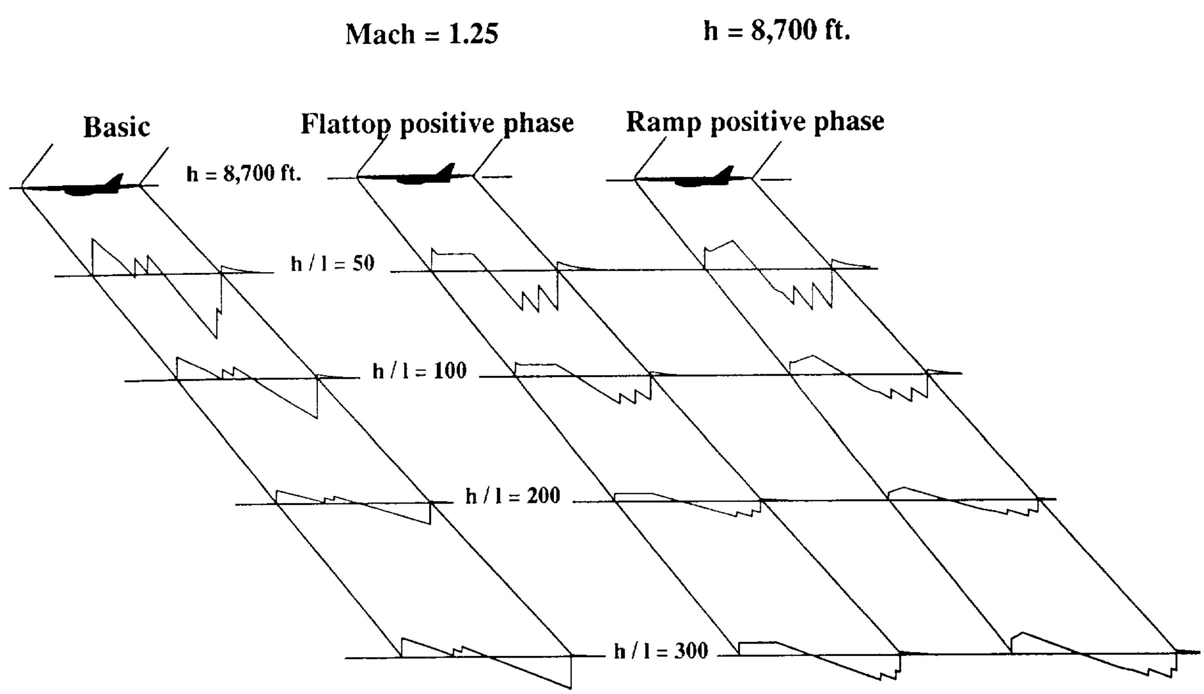

Figure 17

FIREBEE SONIC BOOM FLIGHT TEST SETUP

An indication of the manner in which sonic boom measurements will be acquired during the Firebee flight tests is presented in figure 18. Shown in the figure are schematic illustrations of the Firebee flying at the design conditions (relative to boom signature modifications) of Mach 1.25 and an altitude of 8,700 feet and also an off-design condition of Mach 1.5 and an altitude of 20,000 feet above ground level over a large array of microphones spaced along the ground track for a total of 3,000 feet and at various distance to each side of the track out to about 2,000 feet. Having such an arrangement eases the constraints of having the vehicle fly exactly along the desired ground track centerline both in terms of its lateral displacement and heading. The microphone separation will also provide an indication of the stability of the atmosphere through which the shock waves propagate and also provide information on character of the signatures at lateral locations. It is planned to make use of the digital-remote self-triggering measurement systems, PATS, developed by NASA-Johnson Space Center (Portable Automated Systems[14]) and USAF BEAR System (Boom Event Analyzer Recorder[15]) shown in the lower portion of the figure. The equivalence of these systems as compared to the previously employed NASA analog sonic boom measurement systems has been demonstrated.[16]

Also shown on the figure is a schematic of an orbiting airborne measurement planform carrying one of the remote-digital boom measurement units aloft to altitudes of 3,000, 6,000 and even 10,000 feet aboard an RPV surveillance vehicle such as the USMC Pioneer. The combination of the relatively slow speed of the vehicle, about 40 miles per hour, and the high signal-to-noise ratio associated with the sonic boom signature (in reference to airflow noise over the microphone) should permit quantitative boom signature measurements. The weight of the digital-remote boom measurement unit is well within the current payload capability of the Pioneer vehicle. However, an initial flight test using the Pioneer airborne sonic boom arrangement would be required to assure that the concept is valid.

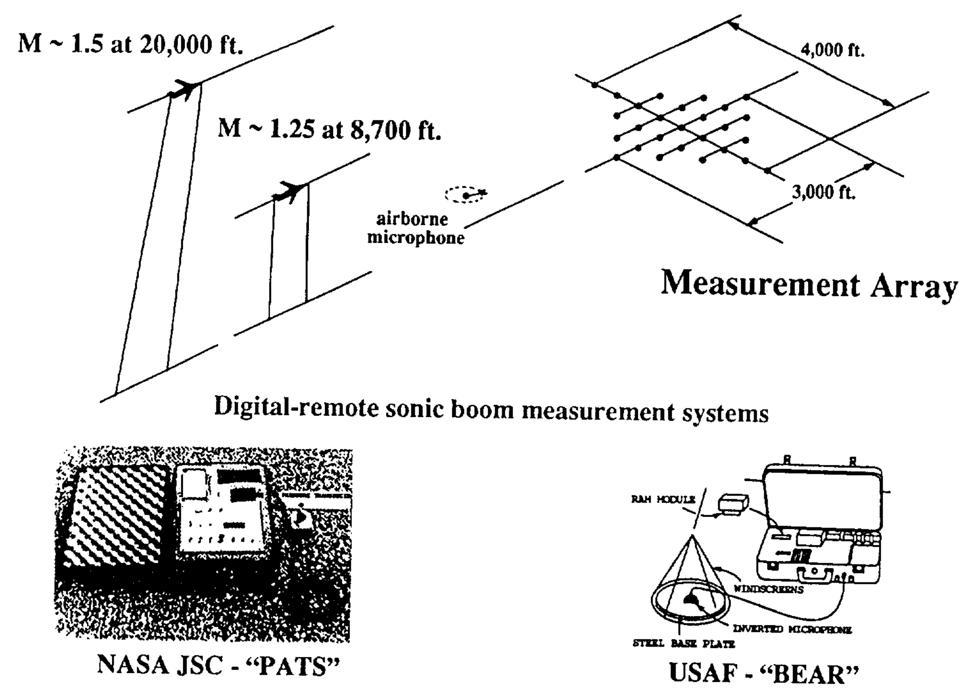

Figure 18

SUMMARY REMARKS

A study has been made to determine the feasibility of experimentally establishing whether a "shaped" sonic boom signature, shown to be "do-able" on wind tunnel models out to about 10 body lengths, will persist out to representative flight conditions of about 200 to 300 body lengths. The study focuses on the use of relatively large supersonic remotely-piloted and recoverable vehicle. Other simulation methods that may accomplish the objectives were also addressed and include the use of nonrecoverable target drones, missiles, full-scale drones, very large wind tunnels, ballistic facilities, whirling-arm techniques, rocket sled tracks, and airplane nose probes.

The feasibility of experimentally establishing the persistence of modified sonic boom signatures to representative flight conditions using a relatively large supersonic remotely-piloted and recoverable vehicle has been established. It has been determined that the Firebee BQM-34 E vehicle is a suitable test vehicle in terms of its adaptability to geometric modifications, operational capabilities regarding Mach-altitude, availability, and costs.

A key ingredient addressed within the study include selection of a modified (shaped) and identifiable sonic boom signature that differs from the normally observed saw-tooth N-wave signatures, is one that is compatible with vehicle geometric alterations. It was determined that nonsymmetric "shaped" signatures would be utilized and include both a flat-top positive phase waveform and a ramp-type positive phase waveform.

The experimental program involved wind tunnel tests on models and full-scale flight tests. Wind tunnel tests would be conducted in the Langley 8-foot Transonic Tunnel at Mach 1.25. It is also highly desirable to conduct tests in the Langley Unitary Plan Wind tunnel at Mach 1.5 for correlation with past sonic boom experience. Flight tests would be conducted at Pt. Mugu, California, with the WSMR, New Mexico, as an alternate site.

- Study has been conducted to examine the feasibility of experimentally demonstrating the persistence of "shaped" boom signatures to very large distances in a real atmosphere
- Study focussed on use of relatively large supersonic recoverable RPV
- Findings confirm feasibility of conducting overflight measurements of sonic boom signatures using Firebee RPV
- Nonsymmetric "shaped" boom signatures will be utilized
- Experimental program involves both W/T test on models and full scale flight tests
- W/T test would be conducted in LaRC 8' TT at Mach 1.25
- Highly desirable to conduct tests in LaRC UPWT at Mach 1.5 for correlation with past sonic boom experience
- Flight tests would be conducted at Pt. Mugu or WSMR

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